E8.2 The transfer function is

\[ G(s) = \frac{5000}{(s + 70)(s + 500)} \, . \]

The frequency response plot is shown in Figure E8.2. The phase angle is computed from

\[ \phi = -\tan^{-1} \frac{\omega}{70} - \tan^{-1} \frac{\omega}{500} \, . \]

The phase angles for \( \omega = 10, 100 \) and 700 are summarized in Table E8.2.

<table>
<thead>
<tr>
<th>( \omega )</th>
<th>10</th>
<th>200</th>
<th>700</th>
</tr>
</thead>
<tbody>
<tr>
<td>(</td>
<td>G(j\omega)</td>
<td>)</td>
<td>-16.99</td>
</tr>
<tr>
<td>( \phi ) (deg)</td>
<td>-9.28</td>
<td>-92.51</td>
<td>-138.75</td>
</tr>
</tbody>
</table>

**TABLE E8.2** Magnitude and phase for \( G(s) = \frac{5000}{(s + 70)(s + 500)} \).

**FIGURE E8.2**
Frequency response for \( G(s) = \frac{5000}{(s + 70)(s + 500)} \).
E8.3 The loop transfer function is

\[ L(s) = \frac{300(s + 100)}{s(s + 10)(s + 40)}. \]

The phase angle is computed via

\[ \phi(\omega) = -90^\circ - \tan^{-1} \frac{\omega}{10} - \tan^{-1} \frac{\omega}{40} + \tan^{-1} \frac{\omega}{100}. \]

At \( \omega = 28.3 \), we determine that

\[ \phi = -90^\circ - 70.5^\circ - 35.3^\circ + 15.8^\circ = 180^\circ. \]

Computing the magnitude yields

\[ |L(j\omega)| = \frac{300(100)(1 + (\frac{\omega}{100})^2)^{\frac{1}{2}}}{\omega 10(1 + (\frac{\omega}{10})^2)^{\frac{1}{2}} 40(1 + (\frac{\omega}{40})^2)^{\frac{1}{2}}} = 0.75, \]

when \( \omega = 28.3 \). We can also rewrite \( L(s) \) as

\[ L(s) = \frac{75(\frac{s}{100} + 1)}{s(\frac{s}{10} + 1)(\frac{s}{40} + 1)}. \]

Then, the magnitude in dB is

\[ 20 \log_{10} |L| = 20 \log_{10}(75) + 10 \log_{10}(1 + (\frac{\omega}{100})^2) - 10 \log_{10}(1 + (\frac{\omega}{10})^2) \]
\[ - 10 \log_{10}(1 + (\frac{\omega}{40})^2) - 20 \log_{10} \omega = -2.5 \text{ dB}, \]

at \( \omega = 28.3 \).
**E8.4** The transfer function is

\[ G(s) = \frac{Ks}{(s + a)(s + 10)^2}. \]

Note that \( \phi = 0^\circ \) at \( \omega = 3 \), and that

\[ \phi = +90^\circ - \tan^{-1} \frac{\omega}{a} - 2 \tan^{-1} \frac{\omega}{10}. \]

Substituting \( \omega = 3 \) and solving for \( a \) yields

\[ a = 2. \]

Similarly, from the magnitude relationship we determine that

\[ K = 400. \]

**E9.6** The Bode plot of the closed-loop transfer function is shown in Figure E9.6. The value of \( M_{p,\omega} = 3 \) dB. The phase margin is \( P.M. = 40^\circ \) when \( K = 50 \).

![Figure E9.6](image)

**Figure E9.6**
Closed-loop Bode Diagram for \( T(s) = \frac{50(s+100)}{s^3+50s^2+450s+5000} \).
(a) When $K = 4$, the $G.M. = 3.5$ dB. This is illustrated in Figure E9.8.

**Figure E9.8**
Bode Diagram for $G_c(s)G(s) = \frac{K}{s(s+1)(s+2)}$, where $K = 4$.

(b) The new gain should be $K = 1$ for a gain margin $G.M. = 16$ dB.